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U.S. PATENT APPLICATION

Inventor(s): Staffan JOHANSSON
Erik JONSSON

Invention: Using Geographical Coordinates to Determine Mobile Statsion Time Position for Synchronization During Diversity Handover

NIXON & VANDERHYE P.C.
ATTORNEYS AT LAW
1100 NORTH GLEBE ROAD
8TH FLOOR
ARLINGTON, VIRGINIA 22201-4714
(703) 816-4000
Facsimile (703) 816-4100

SPECIFICATION

USING GEOGRAPHICAL COORDINATES TO DETERMINE MOBILE STATION TIME POSITION FOR SYNCHRONIZATION DURING DIVERSITY HANDOVER

BACKGROUND

This application claims the priority and benefit of United States Patent Provisional Application Serial No. 60/250,475, filed December 4, 2000, entitled "Using Geographical Coordinates to Determine Mobile Station Time Position for Synchronization During Diversity Handover". This application is related to the following United States Patent Applications, all of which are incorporated herein by reference: United States Patent Application Serial Number 60/250,474, entitled "USING STATISTICALLY ASCERTAINED POSITION FOR STARTING SYNCHRONIZATION SEARCHER DURING DIVERSITY HANDOVER", United States Patent Application Serial Number 09/931,580, entitled "DYNAMIC OFFSET THRESHOLD FOR DIVERSITY HANDOVER IN TELECOMMUNICATIONS SYSTEM"; and United States Patent Application Serial Number 09/931,280, entitled "PRELIMINARY PERFORMANCE OF HANDOVER FUNCTIONS IN TELECOMMUNICATIONS SYSTEM".

1. FIELD OF THE INVENTION

The invention pertains to data communications systems, and particularly to diversity handover (e.g., soft handover) in a telecommunications system such as a wideband code division multiple access telecommunications system.

2. RELATED ART AND OTHER CONSIDERATIONS

In a typical cellular radio system, mobile stations (MS), also known as mobile user equipment units (UEs), communicate via a radio access network (RAN) to one or

more core networks. The mobile stations (MSs)/user equipment units (UEs) can be mobile telephones ("cellular" telephones) and laptops with mobile termination, and thus can be, for example, portable, pocket, hand-held, computer-included, or car-mounted mobile devices which communicate voice and/or data with radio access network.

The radio access network (RAN) covers a geographical area which is divided into cell areas, with each cell area being served by a base station. A cell is a geographical area where radio coverage is provided by the radio base station equipment at a base station site. Each cell is identified by a unique identity, which is broadcast in the cell. The base stations communicate over the air interface (e.g., radio frequencies) with the mobile stations within range of the base stations. In the radio access network, several base stations are typically connected (e.g., by landlines or microwave) to a radio network controller (RNC). The radio network controller, also sometimes termed a base station controller (BSC), supervises and coordinates various activities of the plural base stations connected thereto. The radio network controllers are typically connected to one or more core networks.

One example of a radio access network is the Universal Mobile Telecommunications (UMTS) Terrestrial Radio Access Network (UTRAN). The UTRAN is a third generation system which in some respects builds upon the radio access technology known as Global System for Mobile communications (GSM) developed in Europe. UTRAN is essentially a wideband code division multiple access (W-CDMA) system. An undertaking known as the Third Generation Partnership Project (3GPPP) has endeavored to evolve further UTRAN and GSM-based radio access network technologies.

As those skilled in the art appreciate, in W-CDMA technology a common frequency band allows simultaneous communication between a mobile station (MS) and plural base stations. Signals occupying the common frequency band are discriminated at the receiving station through spread spectrum CDMA waveform properties based on the use of a high speed, pseudo-noise (PN) code. These high speed PN codes are used to modulate signals transmitted from the base stations and the user equipment units (UEs). Transmitter stations using different PN codes (or a PN code offset in time) produce signals that can be separately demodulated at a receiving station. The high speed PN modulation also allows the receiving station to advantageously generate a

received signal from a single transmitting station by combining several distinct propagation paths of the transmitted signal. In CDMA, therefore, a mobile station (MS) need not switch frequency when handoff of a connection is made from one cell to another. As a result, a destination cell can support a connection to a mobile station (MS) at the same time the origination cell continues to service the connection. Since the mobile station (MS) is always communicating through at least one cell during handover, there is no disruption to the call. Hence, the term "soft handover." In contrast to hard handover, soft handover is a "make-before-break" switching operation.

Direct sequence code division multiple access (DS-CDMA) thus allows signals to overlap in both time and frequency so that CDMA signals from multiple users simultaneously operate in the same frequency band or spectrum. In principle, a source information digital data stream to be transmitted is impressed upon a much higher rate data stream generated by a pseudo-random noise (PN) code generator. This combining of a higher bit rate code signal with a lower bit rate data information stream "spreads" the bandwidth of the information data stream. Each information data stream is allocated a unique PN or spreading code (or a PN code having a unique offset in time) to produce a signal that can be separately received at a receiving station. From a received composite signal of multiple, differently-coded signals, a PN coded information signal is isolated and demodulated by correlating the composite signal with the specific PN spreading code associated with that PN coded information signal. This inverse, de-spreading operation "compresses" the received signal to permit recovery of the original data signal and at the same time suppresses interference from other users.

In addition to receiving signals transmitted from several different transmitting information sources, a receiver may also receive multiple, distinct propagation paths of the same signal transmitted from a single transmitter source. One characteristic of such a multipath channel is an introduced time spread. For example, if an ideal pulse is transmitted over a multipath channel, the corresponding signal appears at the receiver as a stream of pulses, each pulse or path having a corresponding different time delay, as well as different amplitude and phase. Such a complex received signal is usually referred to as the channel impulse response (CIR).

A CDMA receiver employs a multipath search processor that searches for and identifies the strongest multipaths along with their corresponding time delays. A RAKE demodulator captures most of the received signal energy by allocating a number of parallel demodulators (called RAKE "fingers") to the strongest multipath components of the received multipath signal as determined by the multipath search processor. The RAKE finger outputs are diversity-combined, after corresponding delay compensation, to generate a "best" demodulated signal that considerably improves the quality and reliability of communications in a CDMA cellular radio communications system.

The multipath search processor, (sometimes referred to herein as simply a "searcher"), identifies the channel impulse response of a complex received signal in order to extract the relative delays of various multipath components. The searcher also tracks changing propagation conditions resulting from movement of the mobile station or some other object associated with one of the multipaths to adjust the extracted delays accordingly.

More specifically, the channel impulse response of a received multipath signal is estimated within a certain range of path arrival times or path arrival delays called a "search window." All signals detected within the search window form the delay profile, but only those signals originated by the transmitter belong to the channel impulse response. The remaining received signals in the delay profile are noise and interference. When the signals forming the delay profile are represented by their respective powers and delays, the delay profile is called a power delay profile (PDP).

Space diversity is attained by providing multiple signal paths through simultaneous links from a mobile station through two or more base stations. When the mobile station is in communication with two or more base stations, a single signal for the end user is created from the signals from each base station. As mentioned above, this diversity communication is sometimes referred to as a diversity, "soft" handover in that communication with a destination base station is established before communication with the source base station is terminated. Thus, after a call is initiated and established between a mobile station and a serving base station, the mobile station continues to scan a broadcast signal transmitted by base stations located in neighboring cells. Broadcast signal scanning continues in order to determine if one of the neighboring base station transmitted signals is strong enough for a handover to be initiated. If so, this

determination is provided to the radio network which sends the appropriate information to the mobile station and to the new destination base station to initiate the diversity handover. The new base station searches for and finds the mobile station's transmitted signal using the associated spreading code. The destination base station also begins transmitting a downlink signal to the mobile station using the appropriate spreading code. The mobile station searches for this downlink signal and sends a confirmation when it has been received.

Diversity handover requires timing synchronization between the source and destination base stations and the mobile station. Synchronization should be achieved as rapidly and as simply as possible. In the downlink direction (from the base station to the mobile station), the mobile station locates and uses a known pilot signal contained in the base station broadcast channels to temporarily synchronize with the radio network system time. In the uplink direction (from the mobile station to the base station), a known pilot signal transmitted from the mobile station permits the source base station to estimate the channel impulse response for the uplink channel. Using this channel impulse response, the source base station derives synchronization signals necessary to extract the known pilot symbols from the received signal samples. Initial synchronization process occurs after the mobile station performs a random access over an uplink random access channel to acquire a traffic channel from the base station. At the completion of a successful random access procedure, the source base station is synchronized to the first arrived and detected multipath signal component originated by the mobile station and thereafter extracts pilot symbols later transmitted by the mobile station on the uplink traffic channel. For the W-CDMA context, radio interface synchronization in general is described in 3GPP TS 25.402. V3.3.0 (2000-09), which is the Technical Specification Group Radio Access Network, Synchronization in UTRAN Stage 2 (Release 1999) of the 3rd Generation Partnership Project.

During the synchronization procedure for the destination base station, a difficulty arises because there is an unknown propagation delay from the destination base station and the mobile station, and an unknown propagation delay from the mobile station to the destination base station. The sum of these propagation delays is called the round-trip delay, and it determines the delay between the transmit timing of the destination base station and the time when the signal is received at the mobile station. Namely, the

mobile station receives the signal transmitted from the destination base station after a certain propagation delay from the instant when the signal is transmitted. The transmitted signal from the mobile station is synchronized with the received signal at the mobile station, so the transmitted signal from mobile station is delayed with respect to the base station transmission. The additional propagation delay from mobile station to the base station makes the delay of the received signal at the base station equal to the round-trip propagation delay.

The round-trip propagation delay is unknown in diversity handover because there is no random access uplink channel communication between the mobile station and the destination base station like there was with the source base station when the call connection was initially established. During the random access process, the propagation delay between the source base station and the mobile station is measured and used to facilitate the source base station synchronization. Since the round-trip delay between the mobile and destination base station is unknown, the searcher in the destination base station must scan all possible multipaths that could be generated by the mobile station located anywhere in the cell corresponding to the destination base station.

Since maximum delay of the received signal from the mobile station is unknown, a longer search window may be used to cover the maximum possible round-trip propagation delay, which corresponds to the destination base station cell size. As an example, a base station cell having a ten kilometer radius would have a corresponding maximum round-trip propagation delay of approximately eighty microseconds. A typical search window used in the source base station is on the order of ten microseconds. However, the search window in the destination base station would need to be eight times longer in order to accommodate the 80 microsecond propagation delay for this ten kilometer radius cell. Such a long search window is undesirable because of the increased data processing and memory resources required to perform the larger number of search and demodulation operations associated therewith. This large number of operations means increased synchronization delays. A longer search window therefore lessens the ability of the destination base station to respond to changes in the radio channel which translates, ultimately, into increased bit errors in the RAKE receiver outputs.

What is needed therefore, and an object of the present invention, is a technique which provides rapid synchronization of the destination base station receiver to the mobile station's uplink transmission in a diversity handover situation.

BRIEF SUMMARY OF THE INVENTION

A telecommunications system comprises a source base station, a destination base station having a synchronization searcher, and a synchronization start position determination unit which establishes a start position of a synchronization search window for the synchronization searcher of the destination station. The synchronization search window detects, for synchronization purposes, a transmission of the specified mobile station received at the destination base station during a handover of a connection involving the specified mobile station from the source station to the destination base station. In accordance with an aspect of the present invention, the synchronization start position determination unit establishes the start position of the synchronization search window with reference to a calculated distance of the mobile station from the destination base station.

In an example mode of the invention, the synchronization start position determination unit establishes the start position by calculating a distance from a geographical coordinate position of the mobile station to a geographical coordinate position of the destination base station. The synchronization start position determination unit thus establishes the start position of the synchronization search window with reference to a perceived geographical location of the mobile station, the perceived geographical location being a geographical coordinate position of the mobile station.

In an example deployment, the synchronization start position determination unit calculates the distance of the mobile station from the destination base station at a radio network control node of a code division multiple access communication system. The radio network controller node communicates the start time position to the destination base station.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of preferred embodiments as illustrated in the accompanying drawings in which reference characters refer to the same parts throughout the various views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

Fig. 1A is a schematic view of portions of telecommunications system according to an example, non-limiting embodiment of the present invention, showing a pre-soft handover situation.

Fig. 1B is a schematic view showing the system of Fig. 1A during a soft handover situation.

Fig. 2 is a diagrammatic view of a search area for a searcher of a destination base station.

Fig. 3 is a diagrammatic view showing interworking of various functions with a synchronization start position determination unit/process of the present invention.

Fig. 4 is a diagrammatic view illustrating a circularly expanding search of a search area in accordance with an aspect of the present invention.

Fig. 5 is diagrammatic view of example mobile communications system in which the present invention may be advantageously employed.

Fig. 6 is a simplified function block diagram of a portion of a UMTS Terrestrial Radio Access Network, including a mobile station (MS) station; a radio network controller; and a base station.

Fig. 7 is a schematic view of an example RNC node in accordance with one embodiment of the invention.

Fig. 8 is a schematic view of an example base station node in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

Fig. 1A shows a telecommunications system which comprises a source base station BS_s, a destination base station BS_D having a synchronization searcher S, and a control node CN. The source base station BS_s serves a cell C_1; the destination base station BS_D serves a cell C_2. The control node CN controls the source base station BS_s and the destination base station BS_D.

At the time shown in Fig. 1A, a mobile station (MS) has a call connection leg CL_1 over the air interface Iua only with source base station BS_s. But as the mobile station (MS) moves in the direction of arrow D (see Fig. 1A), the mobile station (MS) enters a region (shown as an overlap of cells C_1 and C_2 in Fig. 1B) in which transmissions from the base station destination BS_D can also be received by mobile station (MS). When the strength of the transmissions received from base station BS_D so justify, an additional leg CL_2 of the connection with the mobile station (MS) is added through base station BS_D (see Fig. 1B) in a soft handover operation.

The present invention particularly concerns a soft handover situation such as that described above wherein, for a user equipment unit having an leg of a connection already established with the source base station, a further leg of the connection is established with the destination base station. As explained previously, soft handover includes synchronization of the mobile station (MS) with the destination base station. Synchronization of the mobile station (MS) with the destination base station BS_D involves the searcher S at the destination base station BS_D (see Fig. 1B). The searcher S (also known herein as the synchronization searcher) employs a synchronization search window to detect, for synchronization purposes, a transmission of the mobile station (MS) during a handover of a connection to the destination base station BS_D.

Unlike the source base station BS_s, in attempting the synchronization the destination base station BS_D lacks the random access procedure that allows the respective downlink and uplink trip propagation delays between the mobile station (MS) and the destination base station BS_D. Because the propagation delay between the mobile station (MS) and the destination base station BS_D is unknown, without the present invention the searcher S might be forced to scan all possible delays of the known pilot code PN sequence transmitted by the mobile station (MS). If it were required to do so, the searcher S of the destination base station BS_D would have to consider all possible time delays of the known PN code sequence up to a worst case scenario where the mobile station (MS) is located at the edge of the cell border. The number of time delays corresponding to the radius of the cell C_2 served by the destination base station BS_D defines an uncertainty region considerably larger than a typical search window used to track the various paths of a channel impulse response.

Rather than lengthen the search window with its increased data processing, memory, and delay, the present invention provides the searcher S of the destination base station BS_D with a judicious start position for its synchronization search window. In particular, the start position provided to searcher S is predicated upon a calculated distance of the mobile station from the destination base station. Thus, a geographically-ascertained time position serves as the start position of the synchronization search window for the searcher S of the destination base station BS_D. The geographically-ascertained time position is calculated by a synchronization start time determination unit 101. In the example illustrated embodiment, the synchronization start position determination unit 101 is situated at the control node CN of the telecommunications system, and the telecommunications system is a code division multiple access communication system. The control node CN communicates the start time position to the searcher S of the destination base station BS_D.

In a non-limiting example embodiment, the synchronization start position determination unit 101 establishes the start position by calculating a distance from a geographical coordinate position of the mobile station to a geographical coordinate position of the destination base station. The synchronization start position determination unit thus establishes the start position of the synchronization search window with reference to a perceived geographical location of the mobile station, the

perceived geographical location being a geographical coordinate position of the mobile station.

The synchronization start position determination unit 101 calculates a distance D of the mobile station from the destination base station. One manner of performing the calculation is by using Expression 1.

$$\text{Expression 1: } D = \text{Sqrt}[(MS\_x - TCA\_x)^2 + (MS\_y - TCA\_y)^2].$$

In Expression 1, D is the calculated distance between the mobile station and the destination base station, and "Sqrt" means the square root of the bracketed quantity which follows that notation. The term MS_x refers to a first geographical coordinate of the mobile station (e.g., the "x" coordinate in a Cartesian system); the term MS_y refers to a second geographical coordinate of the mobile station (e.g., the "y" coordinate in a Cartesian system). The term TCA_x refers to a first geographical coordinate of the antenna of the destination base station (e.g., the "x" coordinate in a Cartesian system); the term TCA_y refers to a second geographical coordinate of the antenna of the destination base station (e.g., the "y" coordinate in a Cartesian system). The antenna position of the destination base station is typically part of the product information entered into the system and stored in the product inventory. The information is downloaded to the system at system start/restart and used in runtime in various functions. The antenna position of the destination base station is therefore known to the control node.

In the foregoing, it can be surmised that a Cartesian coordinate system has been illustrated for use with Expression 1. However, it should be understood that the invention is not limited to choices of coordinate system, and that other coordinate conventions and systems can instead be utilized.

The time position of the mobile station, MS_tp, is a function of the distance between the mobile station and the destination base station (see Expression 2).

$$\text{Expression 2: } MS\_tp = f(D)$$

In accordance with the present invention, the location of the mobile station is monitored at regular intervals. When a handover is to be performed, the last known position of the mobile station [MS(x,y)] is used to calculate the distance D between the target cell antenna location [TAC(x,y)] and the mobile station MS. This distance D is also a measure of the time position MS_tp of the mobile station MS.

As shown in Fig. 3, the present invention with its synchronization start position determination unit/process 101 can be implemented using an interworking between two other existing processes: a mobile station location monitoring process 3-1 and handover process 3-2. The mobile station location monitoring process 3-1 monitors the geographical position of the mobile station, and reports estimates of the location of the mobile station at regular intervals (as indicated by action 3-3). When the requirements for handover are satisfied (e.g., when the destination base station can be added for a new leg of the connection), the synchronization start position determination unit/process 101 is notified (as indicated by action 3-4). The synchronization start position determination unit/process 101 then uses the latest estimate of the mobile station geographical position to determine the synchronization start position SP for the mobile station. The synchronization start position SP as determined by the synchronization start position determination unit/process 101 is transmitted to the destination base station (BS_D) for use as the start value in the wide search algorithm of the synchronization searcher S.

The geographical location of the mobile station can be monitored by the mobile station location monitoring process 3-1 in various manners. As a first alternative, the signals received and/or transmitted from the mobile station relative can be utilized in ways understood by those skilled in the art to ascertain the approximate geographical coordinates of the mobile station. For example, the geographic location of the mobile station can be ascertained using very accurate clocks and measuring the radio propagation times for the mobile signal relative to different radio base stations. Other more direct alternatives can also be employed, such as utilization of Global Positioning System (GSP) transponders at the mobile station, and broadcast by the mobile station of its GPS coordinates.

In the example illustrated embodiment, the synchronization start time determination unit 101 is situated at a radio network control (RNC) node of the code division multiple access communication system, but can be located at other nodes. The node whereat the synchronization start position determination unit 101 resides communicates the start time position to the synchronization searcher of the destination base station. For example, the start time position can be communicated from the synchronization start time determination unit 101 of the control node to the destination base station BS_D in a radio link setup message on the NBAP interface. When the uplink synchronization procedure is completed, the UE time position is transferred to the synchronization start time determination unit 101 in the control node using a radio ink restore indication message on the NBAP interface.

In performing the uplink synchronization with the mobile station, the searcher searches a search area. For a destination cell having a radius of about 35 kilometers, for example, the searcher divides the search area into thirty steps or slots, each slot being about ten microseconds. The search area is searched by the searcher S, slot by slot, using a search window.

The start position SP calculated by synchronization start time determination unit 101 is a time position (preferably expressed in microseconds) which enables the searcher algorithm of the searcher to know where to commence its evaluation of the received transmission of the mobile station (MS). The start position SP calculated and received from synchronization start time determination unit 101 enables the searcher S to determine with which of its steps or slots to begin its search. For example, the searcher S can center its search window about the slot corresponding to the start position SP calculated and received from synchronization start time determination unit 101.

In the above regard, upon receipt of start position calculated by the synchronization start time determination unit 101, the searcher S of the destination base station BS_D starts looking for a transmission from the mobile station (MS) at the communicated start position SP (e.g., at the average time position calculated by synchronization start time determination unit 101 in the illustrated embodiment). More formally, the searcher S begins looking for the channel impulse response of the signal received from the mobile station (MS) by centering its search window about the start

position SP. Thus, given its rather wide search area SA as illustrated in Fig. 2, the searcher S can intelligently hone in on the start position SP calculated and relayed to it by the synchronization start time determination unit 101.

In accordance with yet another aspect of the present invention, if the mobile station is not found at the start time position SP, in the manner illustrated in Fig. 4 the searcher S attempts to find the transmission of the mobile station by looking at one or more search window positions which neighbor the start time position SP. More particularly, with a failure to find the transmission of the specified mobile station at the start time position SP communicated to it by synchronization start time determination unit 101, the synchronization searcher looks at progressively remote neighboring search window positions relative to the start time position. That is, if the specified mobile station is not found at the start time position SP/1 of Fig. 4, the synchronization searcher attempts to find the transmission of the mobile station by looking at a first neighboring search window position on a first side of the start time position (e.g., position P/2). This is done by centering the search window of the searcher S about the slot which neighbors on the first side the slot corresponding to the start time position SP/1. Then, if necessary, the searcher S looks at a second neighboring search window position (e.g., position P/3) on a second side of the start time position (e.g., centering the search window about the slot which neighbors on the second side the slot corresponding to the start time position SP/1). The first neighboring search window position P/2 on the first side of the start time position and the second neighboring search window position P/3 on the second side of the start time position comprise a set of most neighboring search window positions. Upon failure to find the transmission of the specified mobile station at either of the most neighboring search window positions, the searcher S looks at progressively remote sets of neighboring search window positions, e.g., at positions P/4 and P/5. The searcher S thus looks in a widening circle of search positions about the start search position. Each search position comprises a 10 microsecond step. The search is repeated through as many as thirty steps if necessary until the mobile station (MS) is found. Seen from a statistical point of view, the average duration of the search time will be shortened, while the peak search time is still high.

One non-limiting, example deployment of the present invention is described in the context of a universal mobile telecommunications (UMTS) 10 shown in Fig. 5. A

representative, connection-oriented, external core network, shown as a cloud 12 may be for example the Public Switched Telephone Network (PSTN) and/or the Integrated Services Digital Network (ISDN). A representative, connectionless-oriented external core network shown as a cloud 14, may be for example the Internet. Both core networks are coupled to their corresponding service nodes 16. The PSTN/ISDN connection-oriented network 12 is connected to a connection-oriented service node shown as a Mobile Switching Center (MSC) node 18 that provides circuit-switched services. The Internet connectionless-oriented network 14 is connected to a General Packet Radio Service (GPRS) node 20 tailored to provide packet-switched type services which is sometimes referred to as the serving GPRS service node (SGSN).

Each of the core network service nodes 18 and 20 connects to a UMTS Terrestrial Radio Access Network (UTRAN) 24 over a radio access network (RAN) interface referred to as the Iu interface. UTRAN 24 includes one or more radio network controllers (RNCs) 26. For sake of simplicity, the UTRAN 24 of Fig. 5 is shown with only two RNC nodes, particularly RNC 26_1 and RNC26_2. In Fig. 5, for sake of simplicity only one of the RNC nodes 26 is shown with a synchronization start time determination unit 101 of the present invention. Each RNC 26 is connected to a plurality of base stations (BS) 28. For example, and again for sake of simplicity, two base station nodes are shown connected to each RNC 26. In this regard, RNC 26_1 serves base station $28_{1\text{-}1}$ and base station $28_{1\text{-}2}$, while RNC 26_2 serves base station $28_{2\text{-}1}$ and base station $28_{2\text{-}2}$. It will be appreciated that a different number of base stations can be served by each RNC, and that RNCs need not serve the same number of base stations. Moreover, Fig. 6 shows that an RNC can be connected over an Iur interface to one or more other RNCs in the URAN 24.

A mobile station (MS), such as mobile station (MS) 30 shown in Fig. 5, communicates with one or more base stations (BS) 28 over a radio or air interface 32. Each of the radio interface 32, the Iu interface, the Iub interface, and the Iur interface are shown by dash-dotted lines in Fig. 5.

Preferably, radio access is based upon wideband, Code Division Multiple Access (WCDMA) with individual radio channels allocated using CDMA spreading codes. Of course, other access methods may be employed. WCDMA provides wide bandwidth for multimedia services and other high transmission rate demands as well as robust features

like diversity handoff and RAKE receivers to ensure high quality. Each user mobile station (MS) or equipment unit (UE) 30 is assigned its own scrambling code in order for a base station 28 to identify transmissions from that particular mobile station (MS) as well as for the mobile station (MS) to identify transmissions from the base station intended for that mobile station (MS) from all of the other transmissions and noise present in the same area.

Fig. 6 shows selected general aspects of mobile station (MS) 30 and illustrative nodes such as radio network controller 26 and base station 28. The mobile station (MS) 30 shown in Fig. 6 includes a data processing and control unit 31 for controlling various operations required by the mobile station (MS). The data processing and control unit 31 of the mobile station (MS) provides control signals as well as data to a radio transceiver 38 connected to an antenna 35.

The example radio network controller 26 and base station 28 as shown in Fig. 6 are radio network nodes that each include a corresponding data processing and control unit 36 and 37, respectively, for performing numerous radio and data processing operations required to conduct communications between the RNC 26 and the user equipment units (UEs) 30. The data processing and control unit 36 of the RNC includes the synchronization start time determination unit 101 of the present invention, while the transceivers 38 of the base station 28 includes a searcher S. Part of the equipment controlled by the base station data processing and control unit 37 includes plural radio transceivers 38 connected to one or more antennas 39.

Fig. 7 illustrates, in somewhat more detail, an example non-limiting RNC node 26 of the present invention. It so happens that the RNC node 26 of Fig. 7 is a switched-based node having a switch 120. The switch 120 serves to interconnect other constituent elements of RNC node 26. Such other constituent elements include extension terminals 122_1 through 122_n, as well as extension terminal 124. Extension terminals 122_1 through 122_n essentially function to connect RNC node 26 to the base stations 28 served by RNC node 26; extension terminal 124 connects RNC node 26 across the Iu interface to the core network.

Yet other constituent elements of RNC node 26 include diversity handover unit 126; an ALT unit 128; codex 130; timing unit 132; a data services application unit 134;

and, a main processor 140. The person skilled in the art will appreciate generally the functions of these constituent elements, it being noted that the ALT unit 128 is a unit which provides, e.g., multiplexing and demultiplexing and (optionally) queuing with regard to differing protocols of cells. In one example implementation of the present invention, the synchronization start time determination unit 101 can be performed by the main processor 140.

Fig. 8 illustrates, in non-limiting manner, more details of an example base station (BS) node 28 in accordance with one embodiment of the present invention. As with RNC node 26, the base station (BS) node 28 of Fig. 8 is a switched-based node having a switch 220 which serves to interconnect other constituent elements of base station (BS) node 28. Such other constituent elements include extension terminal 222; ALT unit 228; BS main processor 240, and interface boards 242.

Extension terminal 222 connects base station (BS) node 28 to radio network controller (RNC) node 26, and thus comprises the Iub interface. As in the case of radio network controller (RNC) node 26, the ALT unit 228 is a unit which provides, e.g., multiplexing and demultiplexing and (optionally) queuing with regard to differing protocols of cells. A searcher S is located in each of the receive boards 270 of the transceivers 38.

Details of synchronization searchers in general can be gleaned from one or more of the following United States Patent Applications, both of which are incorporated herein by reference: United States Patent Application Serial Number 09/452,100, entitled "Synchronization of Diversity Handover Destination Base Station"; and United States Patent Application Serial Number 09/070,778, entitled "Search Window Delay Tracking In Code Division Multiple Access Communication System".

The present invention advantageously decreases the duration of the search time, on average, for the wide area search. This means that the delay when adding a new soft handover leg for a connection can be shortened, which in turn means increased capacity and lowered risk for dropped calls at handover.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.